



Idaho National Laboratory

MODULE R

MAINTENANCE RULE IMPLEMENTATION

Maintenance Rule Implementation

- **Purpose:** To acquaint students with ways in which PRA typically supports licensee implementation of the Maintenance Rule.
- **Objectives:**
 - Explain the purposes of the Maintenance Rule and identify areas in which PRA can support the rule's implementation
 - Explain how performance goals/criteria are established using the "EPRI Method"
- **References:**
 - 10CFR50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants
 - Regulatory Guide 1.160, Monitoring the Effectiveness of Maintenance at Nuclear Power Plants
 - NUMARC 93-01, Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants
 - EPRI Technical Bulletin 96-11-01, "Monitoring Reliability for the Maintenance"
 - EPRI Technical Bulletin 97-3-01

Maintenance Rule Description

- **Performance -Based Rule**
- **Effective July 10, 1996**
- **“To monitor the effectiveness of maintenance activities...**
 - **For safety-significant plant equipment...**
 - **In order to minimize the likelihood...**
 - **Of failures and events...**
 - **Caused by the lack of effective maintenance.”**

(Maintenance Rule Training Handouts)

Maintenance Rule Description

- **Paragraph (a)(1)**
 - Monitor performance of "problem" structures, systems, and components (SSCs)
 - Compare performance against goals
 - (a)(1) SSCs
- **Paragraph (a)(2)**
 - Reduced monitoring for SCCs meeting performance criteria
 - (a)(2) SSCs
- **Paragraph (a)(3)**
 - Periodically evaluate program
 - Incorporate industry-wide experience
 - Balance SSC unavailability and failures

Maintenance Rule Description

- **Paragraph (a)(4)**
 - **Assess and manage increase in risk from maintenance activities**
- **Paragraph (b)**
 - **Scope of program**
 - **Safety-related SSCs**
 - **Non-safety-related SSCs**
 - **Mitigate accidents or are in plant Emergency Operating Procedures (EOPs)**
 - **Required for safety-related SSCs to work properly**
 - **Can cause a scram or actuation of safety-related SSC**

Maintenance Rule History

- **1985: Davis Besse loss of all feedwater event**
- **1985-86: Maintenance and Surveillance Program (MSP)**
 - **NUREG-1212, “Status of maintenance in the U.S. Nuclear Power Industry 1985,” June 1986**
 - **Found lack of performance trending, lack of risk consideration, and ineffective root cause correction actions**
- **1988: Policy Statement on Maintenance of Nuclear Power Plants**
- **1990: Process-oriented and performance-based rulemaking packages developed**
- **1991: Performance-based rule adopted (5-year grace period)**
- **1996: Rule implemented**

Typical Maintenance Rule Implementation

- **Combination of traditional engineering analysis and PRA approaches**
 - Reliance on expert panel to make final decisions
- **Overall structure is performance-based approach**
- **Heavy reliance by most utilities on PRA support/information**

PRA Support for Maintenance Rule Implementation

- **Establishing safety significance of SSCs covered by rule**
- **Establishing performance criteria and goals [(a)(1), (a)(2)]**
- **Evaluating balancing of SSC unavailability and reliability [(a)(3)]**
- **Assessing impact on plant risk when SSCs are removed from service for maintenance [(a)(4)]**

Safety Significance of SSCs

- **NUMARC 93-01 recommends use of three (3) importance measures**
 - Core damage frequency (CDF) contribution, top 90% CDF minimal cut sets
 - Risk reduction worth (RRW), $RRW \geq 1.005$
 - Risk achievement worth (RAW), $RAW \geq 2.0$
- **SSCs above cut-off levels for each importance measure are candidates for high safety significance**
- **Expert panel's role is also to consider and compensate for SSCs not in the PRA as well as PRA uncertainties...**

Factors to be Considered in Use of PRA Importance Measures

- **SSC importance vs PRA basic event importance**
 - AFW Motor-driven pump A vs AFW-MDP-FS-A180
- **Sequence truncation level used in PRA**
- **Core damage frequency importance vs large early release frequency importance**
- **Avoid reliance on just one measure of importance**

Some Relevant Statistics – Brunswick IPE

Truncation limit: 1E-10/yr
CDF: 6.34E-6/yr
No. basic events: 1543
No. events after truncation: 291
No. events w/F-V > 0.001: 150
No. events w/RAW > 2: 147

CDF Contribution

No. events in top cutsets
Highest F-V not included
Highest RAW not included
No. events w/F-V > 0.005 not included
No. events w/RAW > 2 not included

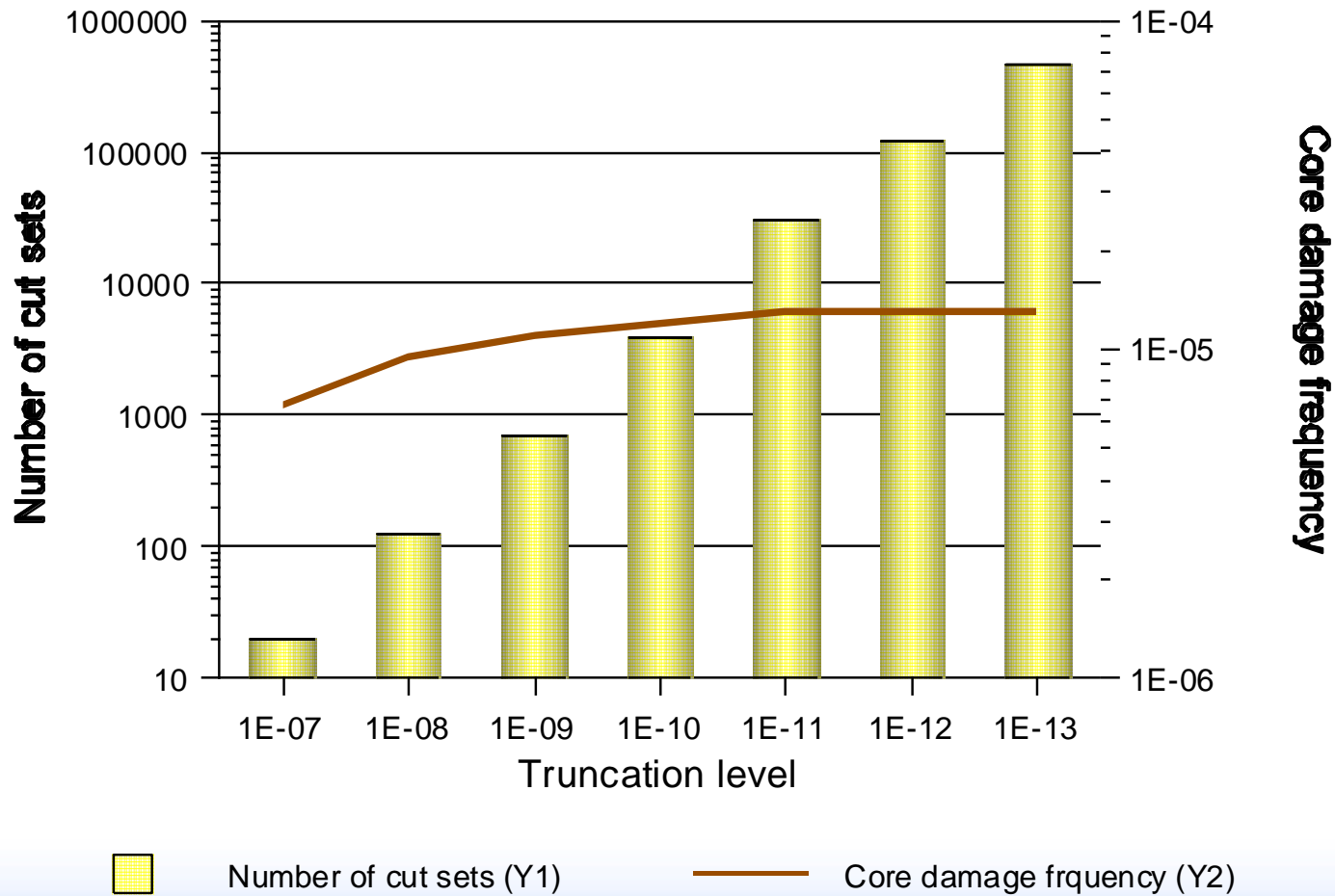
Top 90% Cutsets

184
0.00194
33.3
0
36

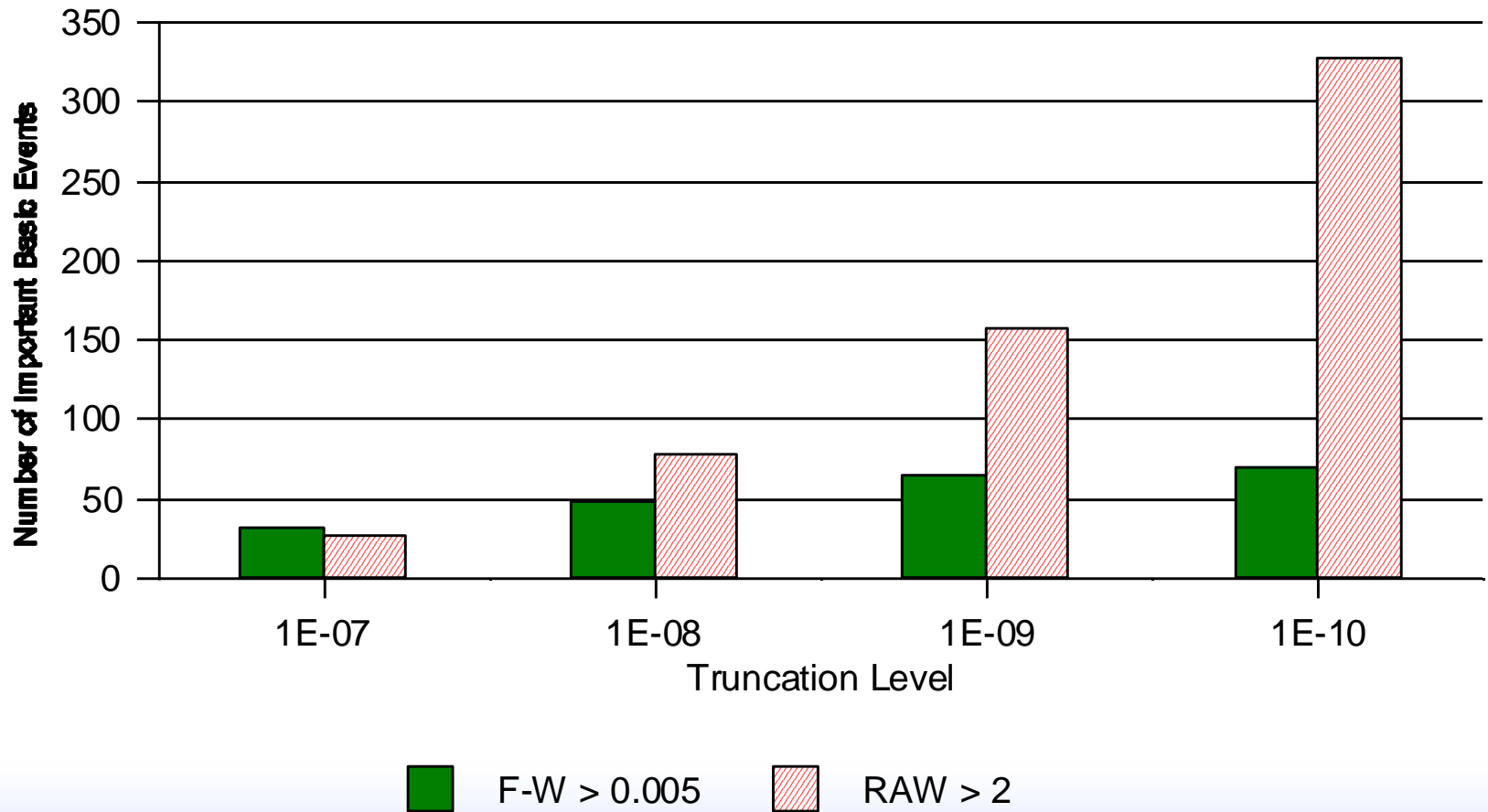
Top 99% Cutsets

281
0.000133
3.67
0
3

Core Damage Frequency and Number of Cut Sets Sensitive to Truncation Limits



Truncation Limits Affect Importance Rankings



SSC Performance Criteria

- **For high safety significance SSCs and standby low safety significance SSCs**
 - **Train-level unavailability and/or unreliability performance criteria**
 - **Unavailability measure - hours unavailable divided by hours plant was at power**
 - **Unreliability measure - number of failures over specified number of demands**
- **Implications of exceeding SSC performance criteria**
 - **SSCs become candidate for category (a)(1), criteria become goals to be met before SSC can be moved back to (a)(2)**

Unavailability Performance Criteria

- **PRA information**
 - Plant-specific historical data
 - Time period covered
 - Generic estimate
- **Other information**
 - System engineer's experience/judgement
 - Industry-wide experience
- **Final choice**
 - Plant-specific data
 - 95% of plant-specific data
 - Other

Unreliability Performance Criteria

- **PRA information**
 - **Plant-specific historical data**
 - **Time period covered**
 - **Generic estimates often used**
- **Other information**
- **Final Choice**
 - **Generally 0, 1 or 2 failures over 2- to 3-year period**
 - **Relation to PRA values**
 - **Estimated or actual demands over 2- to 3-year period used to evaluate against value in PRA**

Performance Criteria Expected to be Commensurate with Safety

- **PRA values used to establish criteria - expectation is met**
- **If PRA values not used**
 - **Unavailability criteria**
 - **Sensitivity analysis if higher than PRA data**
 - **Unreliability criteria**
 - **EPRI approach**
 - **Sensitivity analysis**
 - **Others**
- **Acceptable increase in CDF/LERF not established by NRC**
 - **Not all SSCs expected to perform at limits**

Methods for Establishing Reliability Goals/Criteria

- **EPRI method for reliability on demand (EPRI Technical Bulletin 96-11-01)**
 - Assume failure probability in PRA/IPE is correct
 - Estimate number of demands over next evaluation period
 - Calculate number of failures using binomial distribution such that, if PRA value is correct, there is approximately a 5% chance of seeing more than that number of failure

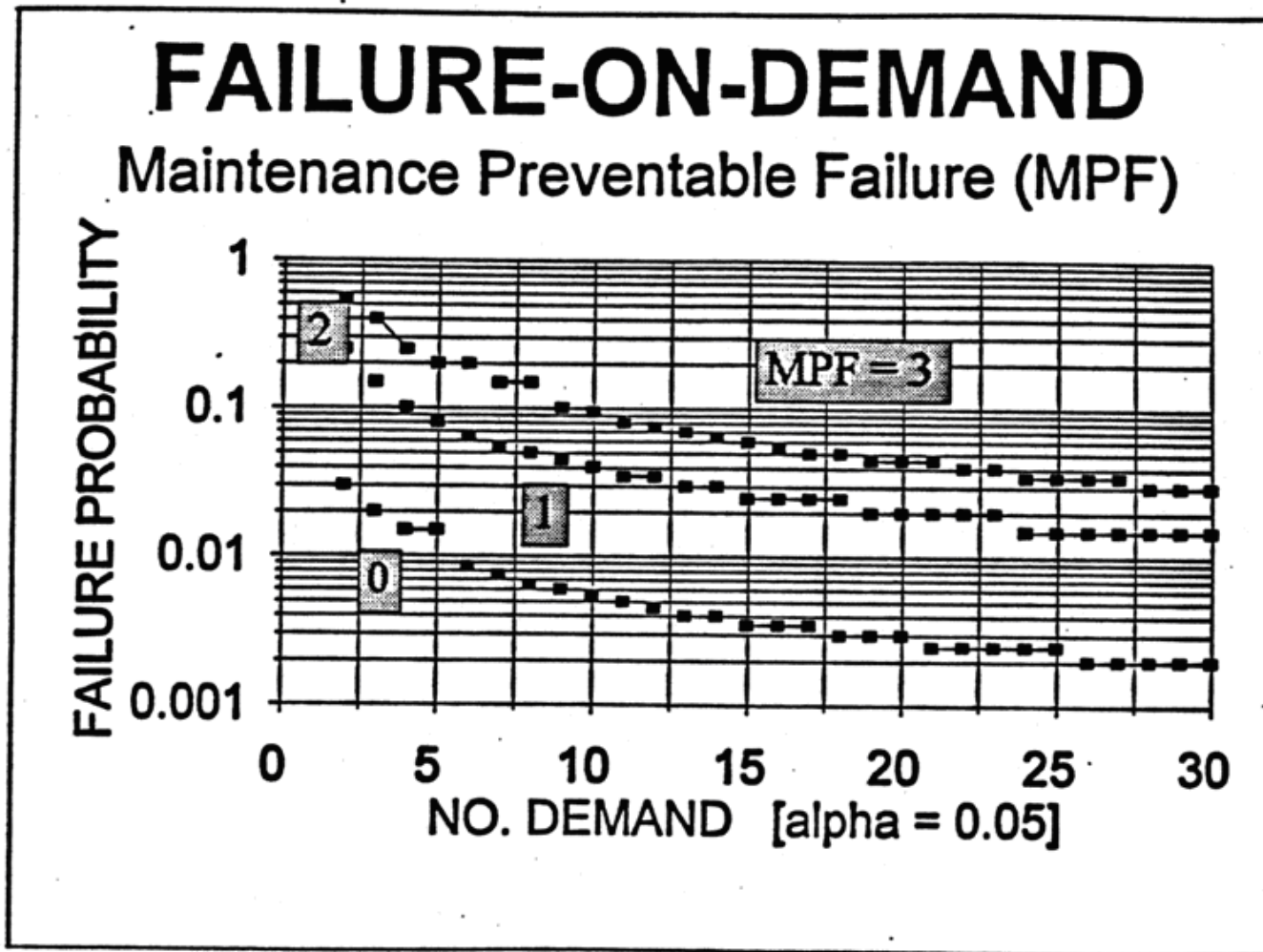
Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 1 – reliability on demand:**
 - **Probability of exactly x failures in 24 demands given p = 0.05 using Binomial**
 - $\Pr(x = 0, \text{ given } p = 0.05, N = 24) = 0.29$
 - $\Pr(x = 1, \text{ given } p = 0.05, N = 24) = 0.37$
 - $\Pr(x = 2, \text{ given } p = 0.05, n = 24) = 0.22$
 - $\Pr(x = 3, \text{ given } p = 0.05, n = 24) = 0.09$
 - **Probability of x failures in 24 demands given p = 0.05 using Binomial**
 - $\Pr(x = 0, \text{ given } p = 0.05, N = 24) = 0.29$
 - $\Pr(x \leq 1, \text{ given } p = 0.05, n = 24) = 0.29 + 0.37 = 0.66$
 - $\Pr(x \leq 2, \text{ given } p = 0.05, n = 24) = 0.29 + 0.37 + 0.22 = 0.88$
 - $\Pr(x \leq 3, \text{ given } p = 0.05, n = 24) = 0.29 + 0.37 + 0.22 + 0.09 = 0.97$
- **Therefore, performance criterion could be set at 3 or fewer failures over the next evaluation period**
 - **A conservative approach would be to set performance criterion of 2 or fewer failures over the next evaluation period**

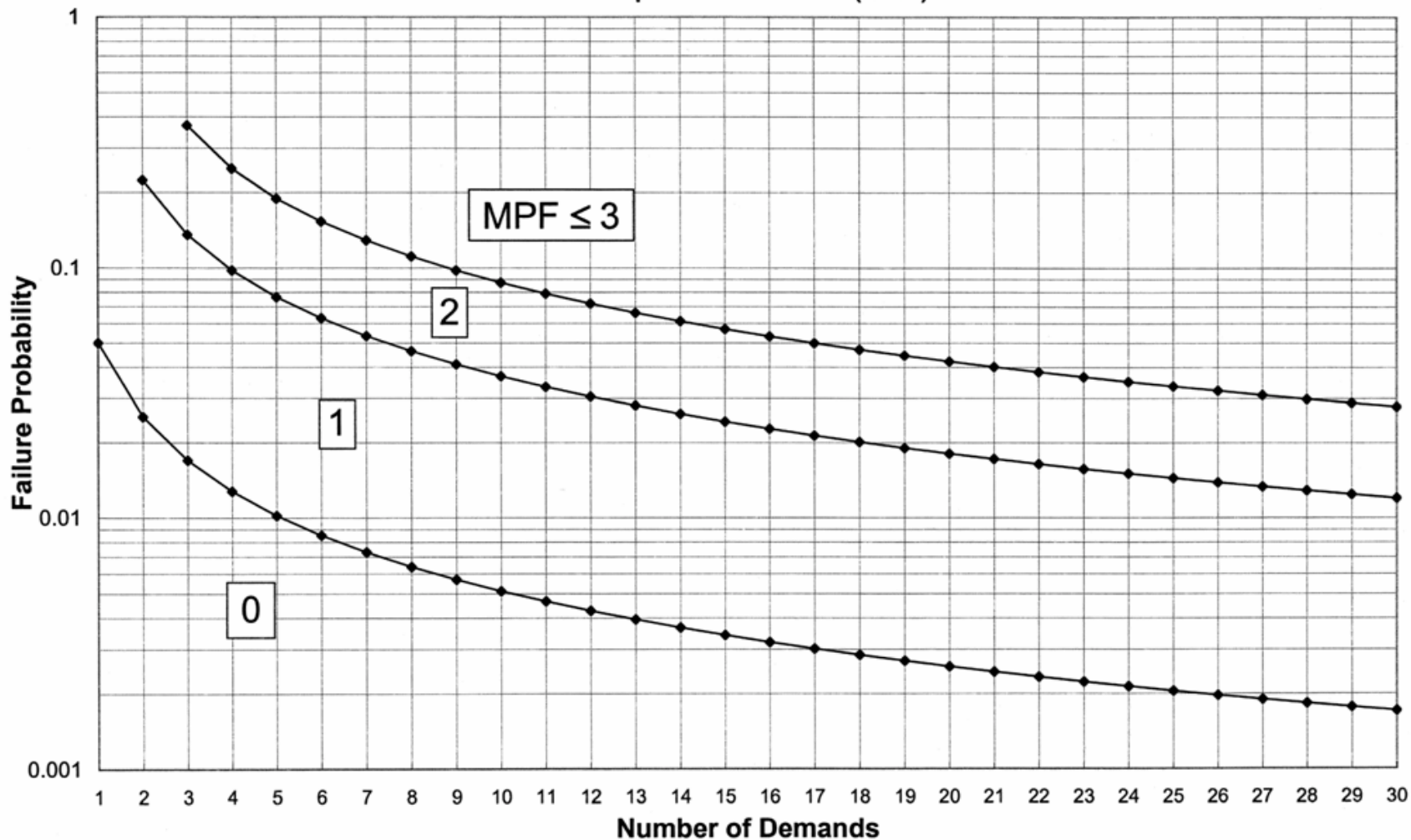
Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 2 – reliability on demand:**
 - **Probability of exactly x failures in 30 demands given $p = 0.01$ using Binomial**
 - $\Pr(x = 0, \text{ given } p = 0.01, N = 30) = 0.74$
 - $\Pr(x = 1, \text{ given } p = 0.01, N = 30) = 0.22$
 - **Probability of x failures in 30 demands given $p = 0.01$ using Binomial**
 - $\Pr(x = 0, \text{ given } p = 0.01, N = 30) = 0.74$
 - $\Pr(x \leq 1, \text{ given } p = 0.01, N = 30) = 0.74 + 0.22 = 0.96$
- **Therefore, performance criterion could be set at 1 or fewer failures over the next evaluation period**
 - **A conservative approach would be to set performance criterion of 0 failures over the next evaluation period**

FIGURE 2



Failure-on-Demand Curves Maintenance-preventable Failures (MPFs)



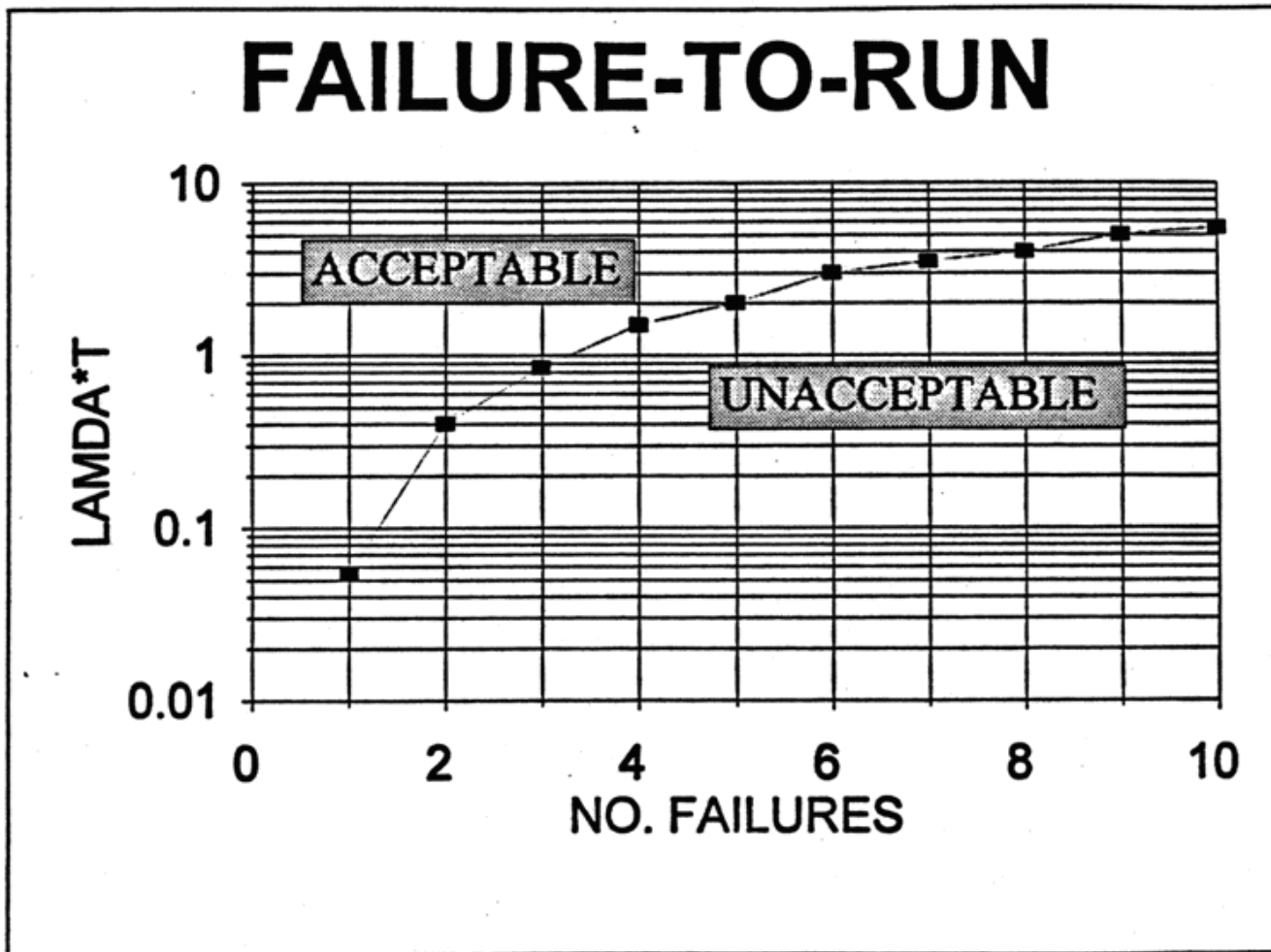
Methods for Establishing Reliability Goals/Criteria (cont.)

- **EPRI method for reliability of normally running SSCs (EPRI Technical Bulletin 97-3-01)**
 - Assume failure rate in PRA/IPE is correct
 - Estimate total running time over next evaluation period
 - Calculate number of failures, using Poisson distribution, such that, if PRA value is correct, there is approximately a 5% chance of seeing more than that number of failures

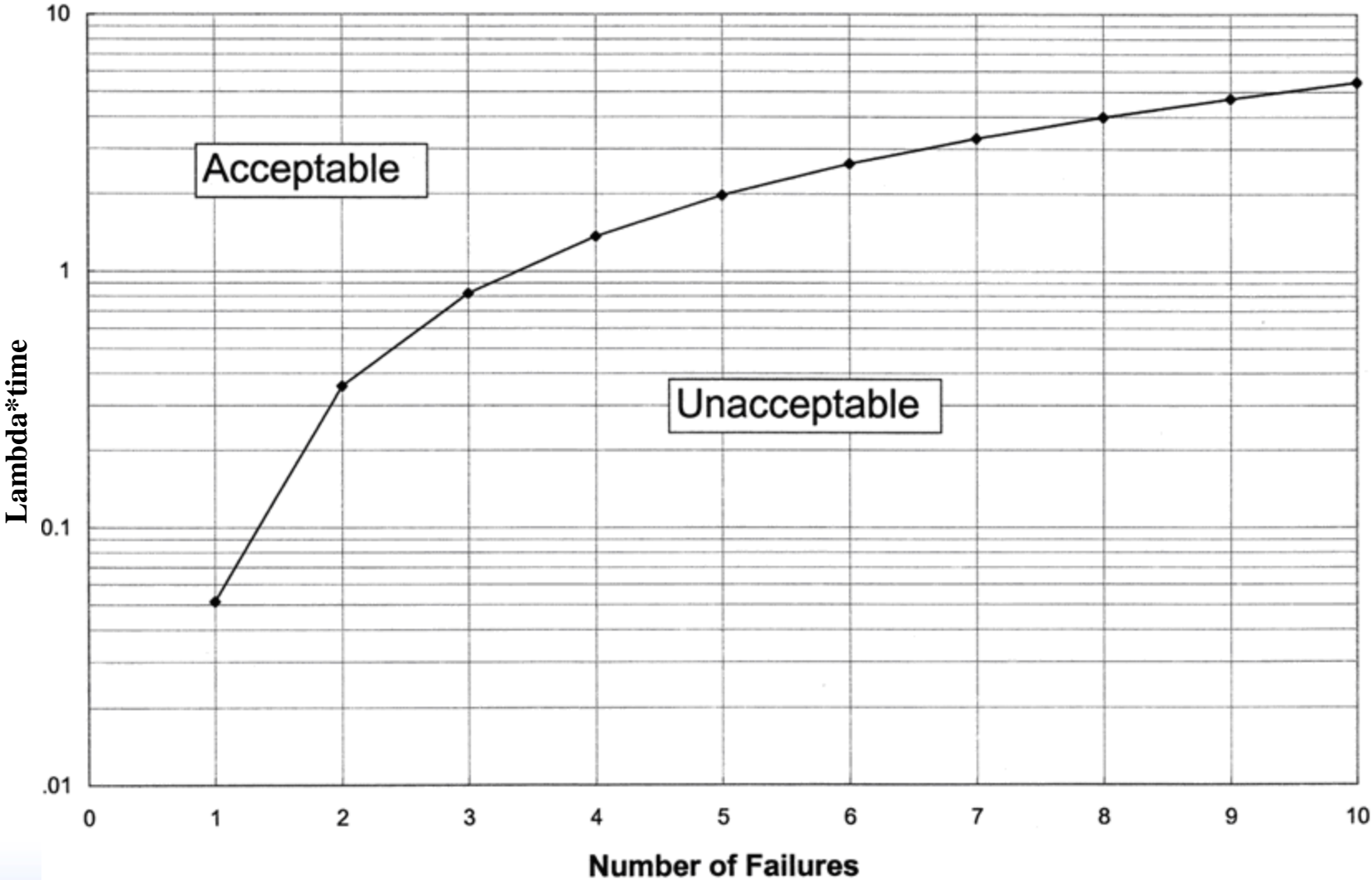
Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 3 – reliability on normally running:**
 - **Probability of exactly x failures in 10,000 hours given that the failure rate (λ) = 5×10^{-5} /hour using Poisson**
 - $\Pr(x = 0, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.61$**
 - $\Pr(x = 1, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.30$**
 - $\Pr(x = 2, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.08$**
 - **Probability of x failures in 10,000 hours given that the failure rate (λ) = 5×10^{-5} /hour using Poisson**
 - $\Pr(x = 0, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.61$**
 - $\Pr(x \leq 1, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.91$**
 - $\Pr(x \leq 2, \text{ given } \lambda = 5 \times 10^{-5}/\text{hour, } t = 10,000 \text{ hrs}) = 0.99$**
- **Therefore, performance criterion could be set at 2 or fewer failures over the next evaluation period**
 - **A conservative approach would be to set performance criterion at 1 or fewer failures over the next evaluation period**

FIGURE 3



Failure-to-Run Curve



Balancing of Unavailability and Unreliability

- **Track SSC unavailability and unreliability**
- **Compare with performance criteria**
- **If performance criteria are approached or exceeded**
 - **Reduce preventive maintenance (if unavailability criterion is exceeded with no failures)**
 - **Increase preventive maintenance (if failure criterion is exceeded with low unavailability)**

Assessing Plant Risk From Maintenance

- **Configuration management**
 - **Work week schedule guidance**
 - 12-week rolling schedule
 - Days of week schedule for SSCs
 - Plant risk matrix or plant status monitor required by Maintenance Rule
 - Operator experience/judgment

Plant Risk Matrix

- **Goal-Assess plant risk given all planned/unplanned SSC maintenance outages**
- **Originally was at least a 2-dimensional matrix covering high safety significance SSC maintenance outages**
 - PRA based
 - Yes or no for planned outages of 2 SSCs, based on PRA estimate of plant risk
 - Guidance for 3 or more planned SSC outages
- **Consideration of emergent failures**

Plant Risk Matrix

Diesel Generator 1	Diesel Generator 2	HPCI	RCIC	Control Rod Drive Hydraulic
DGI	No	Yes*	Yes*	Yes*
	DG2	Yes*	Yes*	Yes
		HPCI	No	No
			RCIC	No

No - High plant risk

Yes - Low plant risk

* Time limitation applies

For Additional Information

- **Maintenance Rule Implementation Inspection Reports (for plants already inspected)**
- **NUREG-1526, Lessons Learned from Early Implementation of the Maintenance Rule at Nine Nuclear Power Plants**
- **Maintenance Rule Guideline Book**